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3. **Network Topology**: Physical & Logical
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4. Transit Note #32 Practical Schemes for Fat-**Tree Network** Construction
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networks, I incorporate **fault**-tolerance into the fat-**tree netw rk**. I present ...
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7. Configuring Spanning **Tree**
Table of Contents Configuring Spanning **Tree** This chapter describes how to configure spanning
Catalyst enterprise LAN switches. ... When you create **fault**-tolerant internetworks, you must...
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8. Fat-**Tree** Routing for Transit
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www.cs.caltech.edu/~andre/abstracts/dehon_sb.html - December 29, 2001 - 2 KB

9. Technical Support **Fault** Decision **Tree**
Technical Support **Fault** Decision **Tree** Prepared by Engineering Dept. Existing Link â€" Was wc
failed recently New Link â€" Never has worked or is working poorly Is the system design ... .
www.wirelessconnections.net/downloads/extras/Fault-Tree-FlowChart.PDF - December 12, 2002 -

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Monitor Every Part of Your Network
Applications for monitoring every device in your network on one management platform ...

Display Detailed Alarm Information and Instructions to Ensure Rapid and Accurate Response to Network Threats
Monitor your entire network from one screen - Create a war-room display of your entire network - Display detailed information for every alarm - Give your staff detailed instructions for every alarm - Filter nuisance alarms - Monitor from any web browser ...

Analyze and Process Alarm Data
Forward alarm data - Export alarms as delimited text for data analysis - Diagnose communication problems ...

Control Remote Site Equipment

Manage Multiple User Security

Automatically Dispatch Repair Personnel
Forward alarms directly to your maintenance staff via pager and e-mail ...

Provide Redundant Backup Monitoring

What Are Other Companies Doing With Their Network Alarm Management Systems?

New York City Transit's $141 million project to create an ATM/SONET network for the 21st century
Carrying over 4 million passengers on an average weekday, the subway system places huge demands on its internal signal, control, and communications network - which, like the trains, must run 24 hours a day, every day of the year ...

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Ping Network Devices

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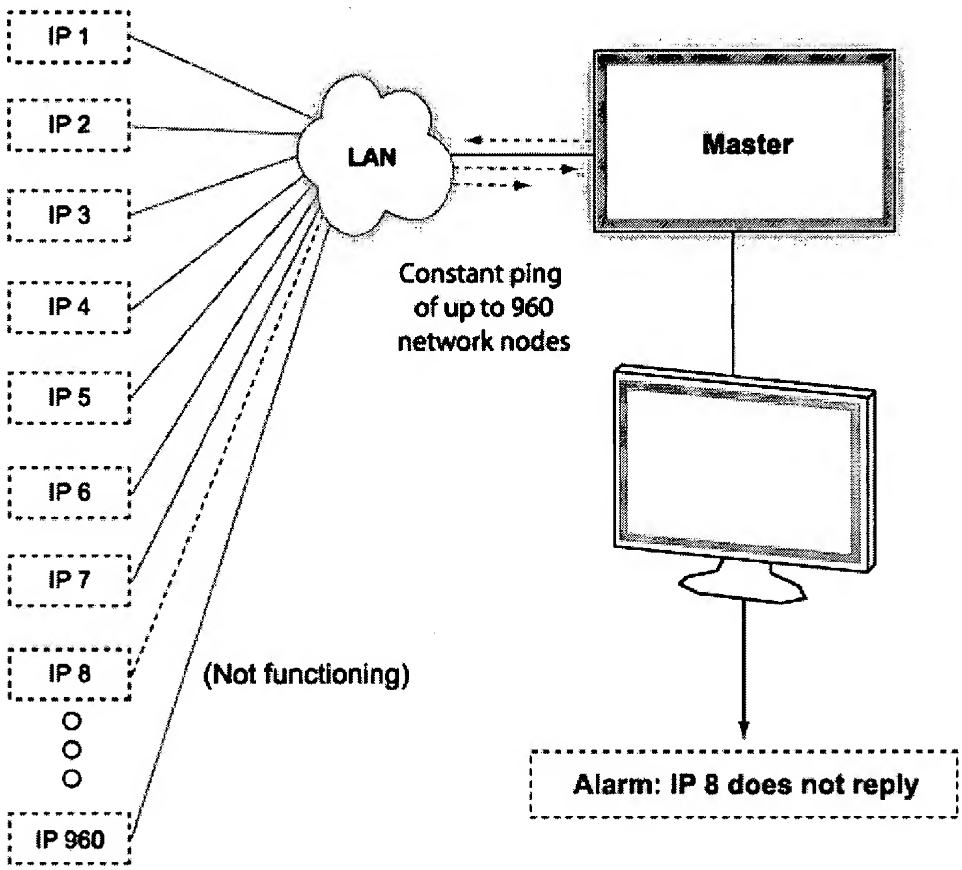

Detect IP Device Failures with Ping Alarms

In this application, the network alarm management system pings IP network devices to confirm continued operation. If a device fails to respond to a ping, an alarm is declared. This provides immediate notification if vital, revenue-generating IP equipment like servers, routers, and gateways fail or go offline. Ping alarm functionality is essential protection for IP networks.

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   Show Me: How This Works | Products That Do This
3. **Monitor Legacy Devices with a Modern Master**
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7. **Combine and Correlate Alarms to Defend Against Complex Threats**
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Diagnose Communication Problems

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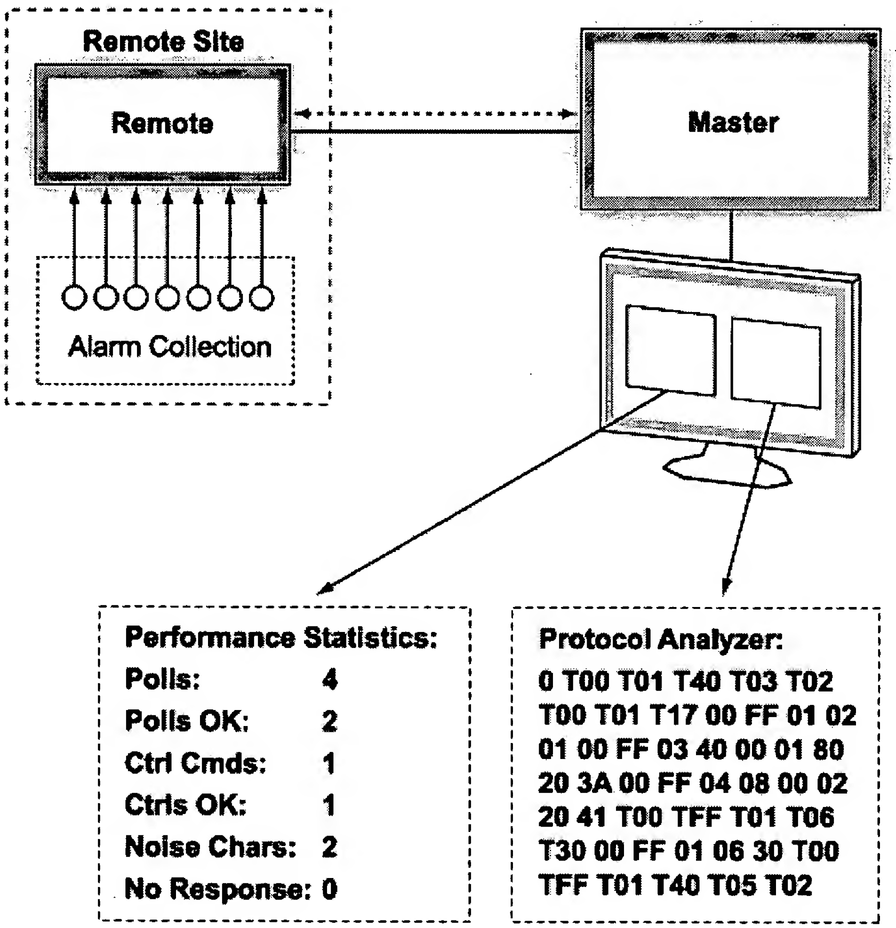

Examine Data Traffic Between Your Master and Remotes

Your network monitoring can be severely compromised if communication between breaks down between your master and your remotes. Yet few network alarm systems provide any means of analyzing data traffic without splicing bulky extra equipment into the communication line.

A high-quality network alarm management system will include full visibility of communication to and from its remotes. Problems in data traffic can be diagnosed directly from the network monitoring screen, examining traffic to and from each site.

You can view a summary report of communication status or observe data traffic directly in hexadecimal format.

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(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2003/0149919 A1**

Greenwald et al.

(43) **Pub. Date: Aug. 7, 2003**

(54) **SYSTEMS AND METHODS FOR DIAGNOSING FAULTS IN COMPUTER NETWORKS**

(76) Inventors: **Joseph Greenwald**, Madbury, NH (US); **Scott Ball**, Newmarket, NH (US); **Christopher Buia**, Dover, NH (US); **Jonathan P. Caron**, Nottingham, NH (US); **David K. Taylor**, Durham, NH (US)

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(21) Appl. No.: **10/258,908**

(22) PCT Filed: **May 7, 2001**

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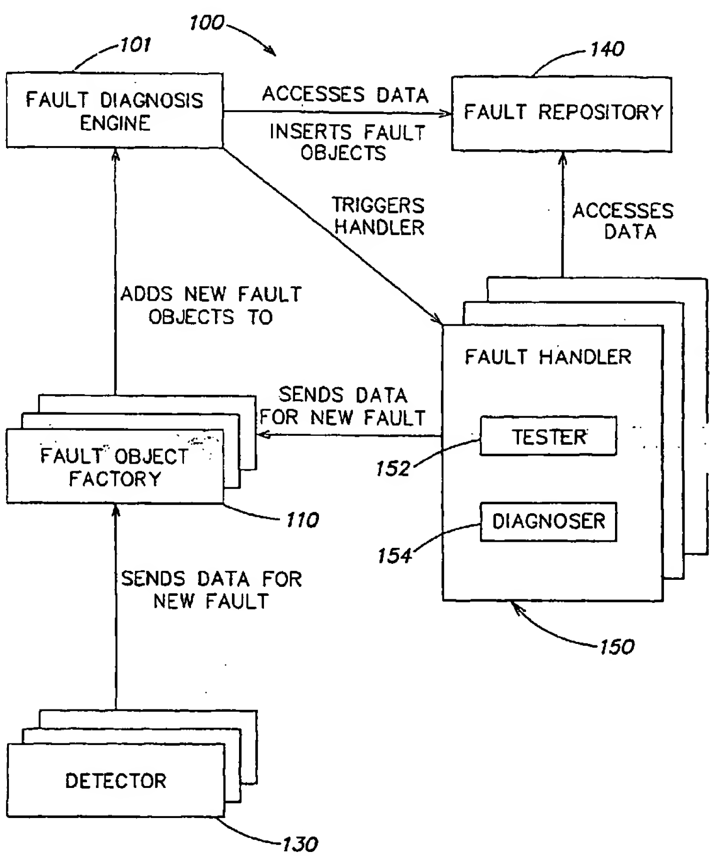
(51) Int. Cl.[7] **H02H 3/05**

(52) U.S. Cl. **714/43**

(57) **ABSTRACT**

A network management system (**10**) includes a fault diagnosis system (**12**) connectable to a communications network (**20**). The fault diagnosis system includes a fault object factory, a path determination module, and a fault diagnosis engine. The fault object factory is constructed and arranged to receive fault data and create fault objects. The path determination module is constructed to determine, in a communications network, a path related to the fault data. The fault diagnosis engine is constructed to perform, using the determined path, a fault analysis on the fault data to diagnose a fault related to the communications network. The network management may also include a help desk system (**18**), a topology mapper (**14**) or an impact analyzer (**16**).



Relex Software
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Relex Fault Tree/Event Tree

Quickly And Accurately Analyze Fault Trees And Event Trees

Widely used in system reliability studies, fault tree analysis offers the ability to focus on an event of importance, such as a highly critical safety issue, and work to minimize its occurrence or consequence. Fault tree analyses are performed using a top-down approach. You begin by determining a top-level event, and then work down to evaluate all the contributing events that may ultimately lead to the occurrence of the top-level event. The probability of the top-level event can then be determined by using mathematical techniques. The resulting fault tree diagram is a graphical representation of the chain of events in your system or process, built using events and logical gate configurations.

FEATURES

- Fast Minimal Cut Set (MCS) Algorithm
- Exact Solutions
- Auto Aligned Graphical Layout
- Importance Measures
  - Birnbaum
  - Criticality
  - Fussell-Vesely
- Common Cause Failures
  - Beta
  - MGL
  - Alpha
  - BFR
- Calculation Methods
  - Cut Set Summation
  - Cross Product
  - Esary Proschan
  - Exact

R lex Interface Streamlines Construction, Provides Flexibility

The trademark Relex user-friendly interface takes the guesswork out of building your diagrams. You can define gates, events, or branches and assign their properties using just a few mouse clicks. You can use standard cut, copy, and paste techniques to add or remove elements throughout your diagrams. Customize the titles, fonts, images, colors, and other parameters so your diagrams meet your own specifications. You can even span complex diagrams across multiple pages for ease of viewing on screen and in print.

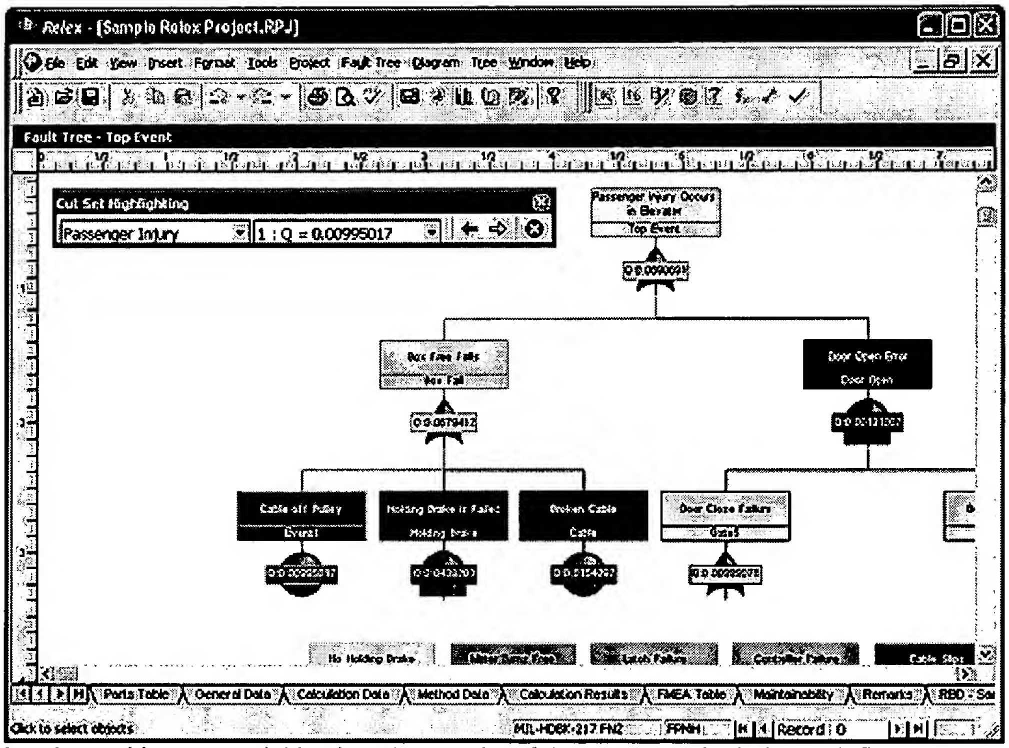
The unique Relex Fault Tree interface provides a simultaneous display of the fault tree in a standard graphical view as well as a compact tabular view. The expandable/collapsible table simplifies the viewing and editing of the properties of the various gates and events, especially in large trees. The graphical fault tree view can be exported as a bitmap or JPEG file to incorporate into reports, presentations, or web pages.

Unique Capabilities Result in Powerful Fault Tree Calculations

Relex Fault Tree supports an impressive array of gate types, such as AND, OR, NOR, NAND, NOT, XOR, Voting, and others. Additionally, Relex Fault Tree provides support for dynamic gates such as Priority AND, Functional Dependency, Spare, and Sequence Enforcing. Various event types, such as Basic, House, and Undeveloped, are also supported. Relex Fault Tree's wide-ranging support of fault tree construction elements is unmatched. Only Relex Fault Tree has the power to quickly and accurately model spares, manage redundancy, and support common cause failures.

Click here for more detailed information about the numerous gate and event types that Relex Fault Tree supports.

Relex Fault Tree supports both quantitative and qualitative analyses, so you can get results as detailed as you require. A number of results are available including reliability, availability, frequency of failures, and the number of failures. Relex Fault Tree incorporates a Minimal Cut Set (MCS) engine that quickly determines the minimal cut sets and offers the capability to view them on screen. You can select between cut set summation, cross product, or Esary Proschan methods for fault tree computations.



Highlighting Cut Sets - You can quickly view the results of the cut set calculations, define gate and events styles with colors, fonts and more.

Relex Fault Tree also supports importance measure computations using the Birnbaum, Criticality, and Fussell-Vesely methods. And, Relex Fault Tree takes into account common cause failures using the Beta, MGL, Alpha, and BFR models.

Relex Event Tree Provides Fast, Accurate Calculations

Relex Fault Tree is augmented with an effective Event Tree module to capably handle your event tree analysis needs. You can use the Relex Event Tree graphical interface to visually map out your event chains using a series of branches representing the event failure and success paths. At the end of each path, your system consequences can be determined. The Relex Event Tree calculation engine can then compute the likelihood of your system's consequences. Relex Event Tree becomes even more powerful when you link your event tree branches directly to Relex Fault Tree for an integrated analysis.

Relex Fault Tree and Event Tree Provide Power and Flexibility

Both Relex Fault Tree and Relex Event Tree are automatically linked with the other software modules in the Relex product line. You can easily incorporate user-defined values and calculated figures from other Relex modules into your fault tree and event tree calculations. You can even use Relex to automatically generate a complete fault tree from an existing FMEA. This feature enables you to visually determine which failure modes contribute to an end effect. Relex Fault Tree and Event Tree provide two tremendously powerful calculation packages wrapped in a unique, flexible interface. These innovative, integrated tools enable you to thoroughly and accurately analyze your product or system safety.

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FEATURE ARTICLE

Fault Tree Gates Logically Link Basic Events to Top Events

Analyze Numerous Hardware Configurations Using Multiple Gate/Event Options

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Fault Tree Analysis (FTA) is well recognized worldwide as an important tool for evaluating safety and reliability in system design, development, and operation. Based on a simple set of rules and logic symbols from probability theory and Boolean algebra, FTA uses a top-down approach to generate a logic model that provides for both qualitative and quantitative evaluation of system reliability. The undesirable event at the system level is referred to as the **top event**. It generally represents a system failure mode or hazard for which predicted reliability data is required. The lower level events in each branch of a fault tree are referred to as **basic events**. They represent hardware, software, and human failures for which the probability of failure is given based on historical data. Basic events are linked via logic symbols (**gates**) to one or more undesirable top events.

Today, computerized FTA is used to analyze very complex systems as well as very complex relationships between hardware, software, and humans. Small fault trees have fewer than 100 events, medium fault trees have from 100 to 1,000 events, and large fault trees have more than 1,000 events! Using good FTA software, you can cut, copy, paste, rearrange, and delete events and gates in various fault tree branches to quickly and easily compare different hardware configurations. An example of a very simple computer-generated fault tree follows.

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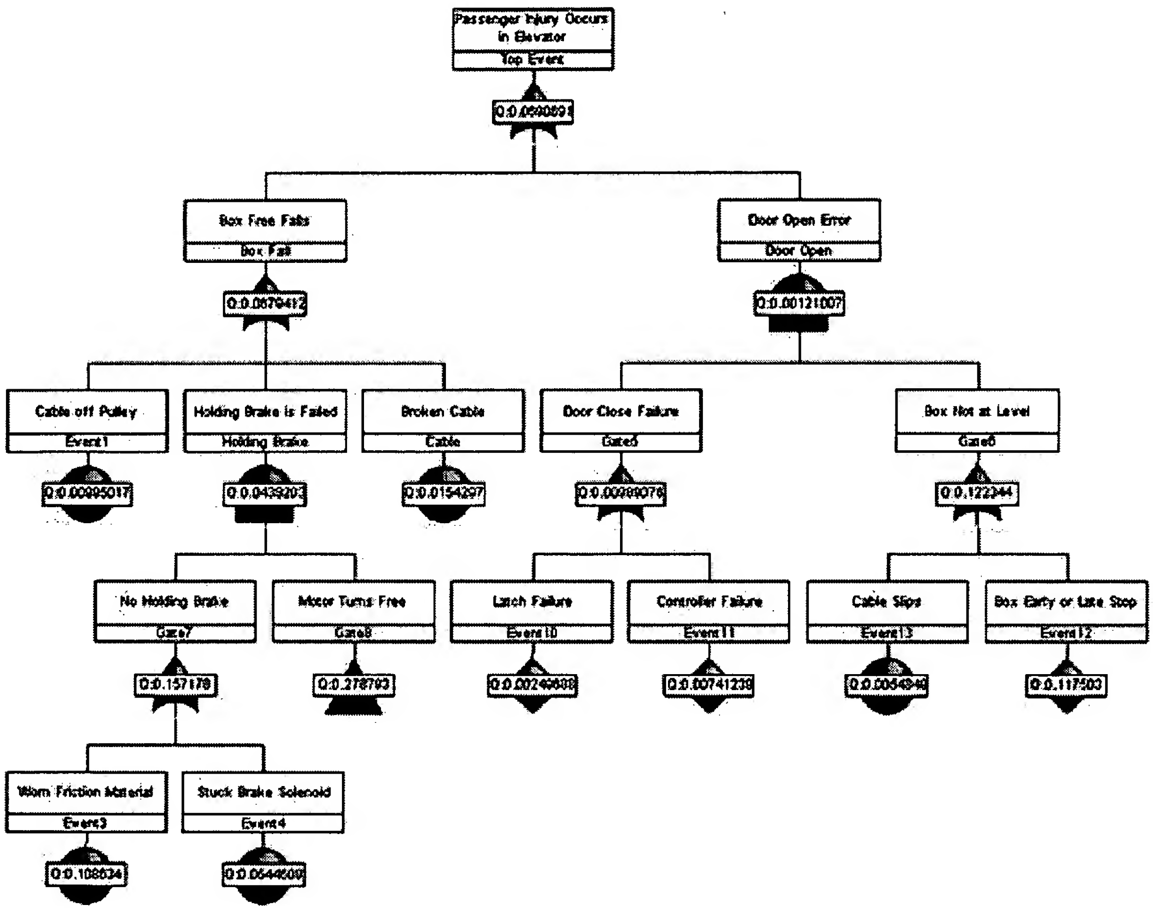


** Generated in Relex Fault Tree. Click the image to view a full-size version.*

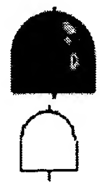
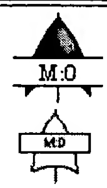
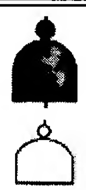
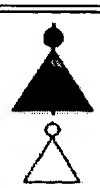
In this fault tree, "Passenger Injury Occurs in Elevator" is defined as the top event. The reasons why passenger injury in an elevator could occur have been determined to be either that the box free falls or that the door is open at an inappropriate time. After determining all possible causes for each event identified, the events and gates for connecting them to higher-level events are added to the fault tree. Any faults that can be further developed to determine causes are then added as lower-level events and connected by the appropriate gates.

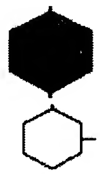
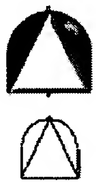
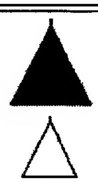
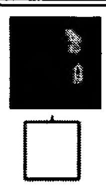
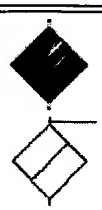
The lowest-level basic events that terminate fault tree paths are often called **terminal events** or **primary events**. They are either component-level events that cannot be further resolved or external events. For example, in the first level of possible events for the free fall of the box, "Cable off Pulley" and "Broken Cable" are terminal events. Because these events are primary faults, they are not developed any further in the fault tree.

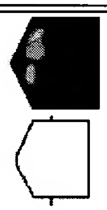
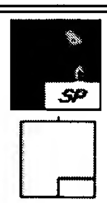
The tables below describe the fault tree gates and events that are implemented in Relex and many other computerized FTA programs. **Note:** Relex Fault Tree is the only commercial software product for reliability analysis that supports dynamic gates (Functional Dependency, Sequence-Enforcing, and SPARE gates). Although a few other competing products support two-input Priority AND gates, none of them perform the dynamic analysis (Markov) required.

Fault Tree Gates

Bitmap/Line Art	Gate Name	Gate Description
	AND Gate	The AND gate is used to indicate that the output occurs if and only if all the input events occur. The output of an AND gate can be the top

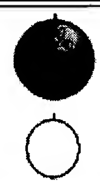
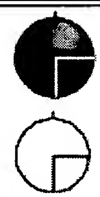
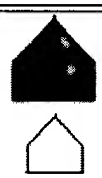
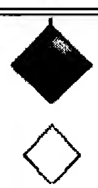
		event or any intermediate event. The input events can be basic events, intermediate events (outputs of other gates), or a combination of both. There should be at least two input events to an AND gate. **Summary of Logic:** All events must be TRUE for the output to be TRUE.
	**OR Gate**	The OR gate is used to indicate that the output occurs if and only if at least one of the input events occur. The output of an OR gate can be the top event or any intermediate event. The input events can be basic events, intermediate events, or a combination of both. There should be at least two inputs to an OR gate. **Summary of Logic:** If at least 1 event is TRUE, the output is TRUE.
	**Voting Gate (m/n)**	The Voting gate (m/n) is used to indicate that the output occurs if and only if m out of the n input events occurs. The m input events need not occur simultaneously. The output occurs when at least m input events occur. When m = 1, the Voting gate behaves like an OR gate. The output of a Voting gate can be a top event or an intermediate event. The input events can be basic events, intermediate events, or combinations of both. **Summary of Logic:** If m = 2 and n = 3, 2 input events must be TRUE for the output to be TRUE.
	**Exclusive OR Gate (XOR Gate)**	The Exclusive OR (XOR) gate is used to indicate that the output occurs if and only if one of the two input events occurs and the other input event does not occur. The output of an XOR gate can be the top event or an intermediate event. The input events can be basic events, intermediate events, or combinations of both. An XOR gate can have only two inputs. **Summary of Logic:** If 1 and only 1 input event is TRUE, the output is TRUE.
	**NAND Gate**	The NAND gate functions like a combination of an AND gate and a Not gate. The NAND gate is used to indicate that the output occurs when at least one of the input events is absent. The output of a NAND gate can be the top event or an intermediate event. The input events can be basic events, intermediate events, or combinations of both. The presence of a NAND gate may give rise to non-coherent trees, where the non-occurrence of an event causes the top event to occur. **Summary of Logic:** If there is at least 1 FALSE event, the output is TRUE.
	**NOR Gate**	The NOR gate functions like a combination of an OR gate and a Not gate. The NOR gate is used to indicate that the output occurs when all the input events are absent. The output of a NOR gate can be the top event or an intermediate event. The input events can be basic events, intermediate events, or combinations of both. The presence of a NOR gate may give rise to non-coherent trees, where the lack of an event causes the top event to occur. **Summary of Logic:** If there is at least 1 TRUE input event, the output is FALSE.
	**Not Gate**	The Not gate is used to indicate that the output occurs when the input event does not occur. The presence of a Not gate may give rise to non-coherent trees, where the non-occurrence of an event causes the top event to occur. There is only one input to a Not gate. **Summary of Logic:** The output is the opposite of the input gate or event.

	**Inhibit Gate**	The Inhibit gate is used to indicate that the output occurs when the input events (I1 and I2) occur and the input condition (C) is satisfied. The output of an Inhibit gate can be a top event or an intermediate event. The input events can be basic events, intermediate events, or combinations of both. **Summary of Logic:** If all input events and the input condition are TRUE, the output is TRUE.
	**Priority AND (PAND) Gate**	The Priority AND (PAND) gate is used to indicate that the output occurs if and only if all input events occur in a particular order. The order is the same as that in which the inputs events are connected to the PAND gate from left to right. The PAND gate is a dynamic gate, which means that the order of the occurrence of input events is important to determining the output. Relex PAND gates support multiple inputs. This is a generalization of an earlier version of the Relex PAND gate where only two inputs were allowed. The output of a PAND gate can be the top event or an intermediate event. The inputs can be basic events or outputs of any AND gate, OR gate, or dynamic gate (Priority AND gate, Functional Dependency gate, Sequence-Enforcing gate, or SPARE gate). (These gates should have the inputs from basic events or other AND gates and OR gates.) You may rearrange items that enter PAND gates to fail in temporal order from left to right to trigger the event. The PAND gate also supports a single input. When only a single input exists, then occurrence of that input will trigger the event. **Summary of Logic:** All input events must be TRUE for the output to be TRUE, and the events should occur from left to right in the temporal order.
	**Transfer Gate**	A Transfer gate is a symbol used to link logic in separate areas of a fault tree. There are two primary uses of Transfer gates. First, an entire fault tree may not fit on a single sheet of paper (or you may want to keep the individual trees small to view and organize them). Second, the same fault tree logic may be used in different places in a fault tree. Through the use of Transfer gates, you can define this logic once and use it in several places. To use a Transfer gate, you insert a Transfer In gate in a fault tree, that links to a Transfer Out gate, which represents the top gate of another fault tree.
	**Remarks Gate**	A Remarks gate is used for the entry of comments. A Remarks gate has no calculation data associated with it, and, therefore, has no effect on calculations. However, the tree branch may continue after a Remarks gate. There can only be one input to a Remarks gate.
	**Pass-Through Gate**	A Pass-Through gate is used for visually aligning the events and gates in a fault tree. A Pass-Through gate extends a vertical connector for visual alignment. A Pass-Through gate has no calculation data associated with it, and, therefore, has no effect on calculations. However, the tree branch may continue after a Pass-Through gate. There can be only one input to a Pass-Through gate.
	**Functional Dependency Gate**	The functional dependency (FDEP) gate is used to indicate that all dependent basic events are forced to occur whenever the trigger event occurs. The separate occurrence of any of the dependent basic events has no effect on the trigger event. The FDEP gate has one trigger event and can have one or more dependent events. All dependent events are either basic events or spare events. The trigger event can be a terminal event or outputs of any AND gate, OR gate, or dynamic gate (PAND gate, FDEP gate, Sequence- Enforcing gate, or SPARE

		gate). Dependent events are repeated events that are present in other parts of the fault tree. The FDEP gate is a dynamic gate, which means the temporal order of the occurrence of events is important to analyze this gate. Generally, the output of the FDEP gate is not that important; however, it is equivalent to the status of its trigger event. The FDEP gate can also be used to set the priorities for SPARE gates. For example, if multiple spares are connected to a FDEP gate, after the occurrence of the trigger event, all spares that are connected to the FDEP gate will fail. Upon failure of these spares, the next available good spare in those SPARE gates will replace the failed spares. If there exists a conflict in choosing the next available spare between multiple SPARE gates, the priority will be based on the order of the connection of these spares in the FDEP gate from left to right. **Summary of Logic:** When the trigger event is TRUE, then dependent events are forced to become TRUE. The trigger event must be TRUE for the output to be TRUE.
	**Sequence-Enforcing Gate**	The sequence-enforcing (SEQ) gate forces events to occur in a particular order. The input events are constrained to occur in the left-to-right order in which they appear under the gate. This means that the leftmost event must occur before the event on its immediate right, which must occur before the event on its immediate right is allowed to occur, etc. The SEQ gate is used to indicate that the output occurs if and only if all input events occurs, when the input events must occur in a particular order. The SEQ gate is a dynamic gate, which means the occurrence of the inputs follows a sequential order. In other words, an event connected to a SEQ gate will be initiated immediately after occurrence of its immediate left event. Therefore, if the leftmost input is a basic event, then the SEQ gate works like a cold SPARE gate. The SEQ gate can be contrasted with the PAND gate in that the PAND gate detects whether events occur in a particular order (but the events can occur in any order), whereas the SEQ gate allows the events to occur only in the specified order. The first input (leftmost input) to a SEQ gate can be a terminal event or outputs of any AND gate, OR gate, or dynamic gate (PAND gate, FDEP gate, SEQ gate, or SPARE gate). Only basic events are allowed for all other inputs. You may rearrange the events that enter SEQ gates; however, rearrangement is not allowed if the first input is an output from another gate. **Summary of Logic:** The output is TRUE if and only if all input events are TRUE; but the input events must occur in a particular order.
	**SPARE Gate**	The SPARE gate is used to model the behavior of spares in the system. The SPARE gate is used to indicate that the output occurs if and only if all input spare events occur. All inputs of a SPARE gate are spare events. A SPARE gate can have multiple inputs. The first event (leftmost event) is known as the primary input, and all other inputs are known as alternative inputs. The primary event is the one that is initially powered on, and the alternative inputs specify that they are in standby mode. After a failure, the active/powered unit that is the first available spare from left to right will be chosen to be active. If all units are failed, then the spare will be considered as failed (output occurred). Depending on the dormancy factor of spares, spares can fail even in standby mode. The Relex SPARE gate is more flexible and can

		handle any kind of spares. If the dormancy factor of all spares connected to a SPARE gate is 0, then the spare acts like a cold spare. If the dormancy factor of all spares connected to a SPARE gate is 1, then the spare acts like a hot spare. If the dormancy factors of all spares connected to a SPARE gate are the same (and are between 0 and 1), then the spare acts like a warm spare. If the dormancy factors of its inputs are different, then it handles generalized situations. The SPARE gate is a dynamic gate, which means the temporal order of the occurrence of events is important to analyze this gate. You may rearrange spare events that enter SPARE gates. **Summary of Logic:** All inputs must be TRUE for the output to be TRUE.

Fault Tree Events

Bitmap/Line Art	Event Name	Event Description
	Basic Event	A Basic event is either a component-level event that is not further resolved or an external event. It is at the lowest level in a tree branch and terminates a fault tree path. Component-level events can include hardware or software failures, human errors, and system failures.
	Spare Event	A Spare event is used to specify spares in dynamic fault trees. A Spare event is similar to a basic event in functionality; however, a spare event allows only rates as inputs. The dormancy factor of the spare indicates the ratio of failure rate in the spare mode and the failure rate in the operational mode. Spare events can have a spare pool, which represents the number of identical instances of that event. For example, if a spare pool of an event is 2, there are 2 identical spare components of that spare event. Spare events are restricted to use as either spares to SPARE gates or as dependent events to FDEP gates.
	House Event	A House event can be turned on or off. When a House event is turned on (TRUE), that event is presumed to have occurred and the probability of that event is set to 1. When a House event is turned off (FALSE), it is presumed not to have occurred, and the probability is set to 0. House events are useful in making parts of a fault tree functional or non-functional. When a House event is turned off, the gate that the House event inputs to will be removed from the tree during calculation. By turning that same House event on, the gate that the House event inputs to will be calculated normally. House events are also referred to as trigger events and switching events.
	Undeveloped Event	An Undeveloped event is used if further resolution of that event does not improve the understanding of the problem, or if further resolution is not necessary for proper evaluation of the fault tree. It is similar to a Basic event, but is shown as a different symbol to signify that it could be developed further, even though you have not done so for the analysis. Undeveloped events may be broken down into associated gates and events.

If you would like additional information about FTA and how it is implemented in the Relex Reliability Software Suite, please email info@relexsoftware.com.